2006-18: DESIGN AND IMPLEMENTATION OF AN ADVANCED RESOURCES ECONOMIC AND RISK ANALYSIS COURSE

J. Cunha, University of Alberta

J. C. Cunha is an associate professor at the School of Mining and Petroleum, University of Alberta, Canada. His main research and teaching interests are in the areas of well design, horizontal wells, deepwater developments and risk analysis applied to various petroleum engineering processes. Prior to joining UofA, Cunha has worked for 25 years at Petrobras where, as a senior technical advisor, he worked in a number of onshore and offshore projects in Brazil, various South America countries, Gulf of Mexico, Africa and the Caribbean. Originally a civil engineer from Juiz de Fora Federal University, Brazil, Cunha holds an MSc from Ouro Preto University, Brazil, and a PhD from Tulsa University, USA, both in petroleum engineering. Currently he is the co-chair for the Society of Petroleum Engineers (SPE) Drilling Technical Interest Group, a review chair for SPE Drilling and Completion and a member of various technical journals' editorial committees.

Design and Implementation of an Advanced Resources Economic and Risk Analysis Course

Abstract

Graduate students in an engineering masters or doctoral program tend to naturally concentrate their efforts on the understanding of theoretical issues related to their research area of interest. This will frequently lead to a "cultural" shock when they, after concluding their program, enter or return to the job market. Commonly these professionals will be asked to analyze, develop and/or implement projects based not only on technical premises but also on solid and very well supported economic feasibility studies. Frequently the common graduate academic background does not prepare students for those tasks.

The importance of a thorough understanding of economic issues is even more noticeable in the oil industry, where uncertainties related to oil and gas reserves, prices and government regulations make any long-term project extremely risky.

Based on the abovementioned factors, a graduate course was designed and implemented aiming to prepare the students to deal with the main economic issues and challenges faced by the oil industry. Besides the basics on engineering economics, the course covers advanced material related to budgeting, economic decision tools, scheduling and corporate planning, Monte Carlo simulation and risk analysis for oil industry projects. Economic analysis of operations, production forecasts and its associated costs and expected profits are also studied.

Furthermore, besides the theoretical topics covered, the students are also required to develop a project where actual challenges from the oil industry are analyzed under the perspective of the risks and uncertainties involved. In the project, the associated costs and economic results also have to be determined and scrutinized. All projects are presented in a seminar at the end of the course. In addition, a "Newsletter" analyzing current problems, challenges and industry development is produced weekly by the group during the duration of the course.

This paper gives details about the course experience, methods used for classroom interaction, methodology to choose the project's topic and participants' feedback. Examples of projects developed and main topics covered by the "Newsletter" are also presented.

Introduction

Most engineering programs across North America[1,2] have in their core curriculum an Engineering Economy course. Petroleum engineering programs generally have in addition a course on Oil & Gas Property Evaluation.

On the graduate level, this structure is not always repeated. Masters and Doctoral programs tend to concentrate on the core petroleum engineering disciplines. In addition to those courses, students may be asked to take courses outside of the department, in advanced mathematics or numerical modeling and also other closely related disciplines such as geostatistics, geology and geomechanics.

The lack of familiarity with engineering economy and the specifics of economic and risk analysis for the oil industry may be even more noticeable in graduate students with a non petroleum engineering background. It is very common to have in petroleum engineering graduate programs students which original bachelor's degree is mining, civil, chemical or mechanical engineering. Those students normally have no background on application of engineering economy to petroleum industry projects.

The petroleum industry, as well as the mining industry, carries very high risk in its exploration and production projects. In addition to the inherent risky reserves quantification, external factors like the always unstable oil and gas market, the constant changes in government regulations and the political environment, make mandatory the use of economic and risk analysis for most projects under evaluation.

Reference 2 indicated the fast-changing requirements of the oil industry, where there is an expectancy that young professionals will be prepared to exercise leadership, deal with business issues and implement policies that will contribute to corporate success and profitability. These issues were previously mentioned in Ref. 3, where oil industry executives pointed out that, while the majority of students are technically well prepared, they lack business related skills and knowledge of current major financial challenges faced by the industry.

The course "Advanced Resources Economic and Risk Analysis" was designed having in mind the abovementioned set of conditions. The main idea was to (1) give the students a review on the basics of Engineering Economy; (2) introduce the students to risk analysis, uncertainty evaluation and decision making tools; (3) discuss actual industry cases showing the use of risk and economic analysis on a number of industry projects; (4) allow each student to develop a project where risk and economic analysis could be used, either on a realistic industry project or as part of the research being developed by the student in his/her graduate program. A fifth objective was to familiarize the student with the trends of the oil industry and its recent major developments. For that matter, a weekly assignment for publication of a "Newsletter" was given at the beginning of the course. The "Newsletter" should have news and analysis on the main industry developments and challenges.

Course syllabus

The main points discussed in classroom were:

1) The Decision Making Process
2) Review on Economic Engineering
3) Risk Analysis
   a. Definition;
   b. Decision tree analysis;
   c. Uncertainty analysis;
   d. Review on probability and statistics;
   e. Sensitivity analysis.
4) Implementation of Risk Analysis

a. Petroleum Engineering applications.
5) Error and Uncertainty
6) Case Studies
7) Government Policies and Regulations

In items 3, 4 and 5 various examples available in the current literature were discussed[4,5,6,7,8]. A computer software for Monte Carlo simulation of simple problems was distributed. Students were allowed to use the software in their projects although they were strongly encouraged to develop more sophisticated tools or use other robust simulation tools available in the computer lab. It is important to notice that graduate students in petroleum engineering normally have good computer simulation skills since many of the technical disciplines involve the use or development of complex simulators.

The course, when taught for the first time, had 11 students enrolled. The group had seven MSc. students and four Ph.D. students. Most of the students were from the petroleum engineering program, with two students from chemical engineering and one from mining. With few exceptions, the group presented in the initial assessment little knowledge about the basics of Engineering Economy and about the possibility of using risk analysis tools in various engineering processes. Even though they knew about the existence of certain economic and risk analysis tools and wish to use it in their research, they faced the issues related to uncertainty quantification and its use for project analysis as something unfamiliar and somehow, unattained.

Obviously, due to the small number of students, this appraisal cannot be extrapolated or assumed to be representative of petroleum engineering graduate students. However, since most programs do not carry courses in these specific subjects, we probably should expect similar lack of familiarity from the average graduate petroleum engineering student.

Specific topics in the syllabus where taught using actual examples from the oil industry. For example, after going over the theory related to "Decision Tree Analysis," examples of application of the methodology[9,10] in existent industry problems were discussed in class giving the students an opportunity to verify advantages and limitations of the method described. In the same way, when looking into the "Decision Making Process," the concept of EMV (Expected Monetary Value) was discussed using actual examples from the literature[11].

It is important to mention that, even though a number of articles were used in the course, those articles were not the main source of information regarding the topics contained in the Syllabus. A textbook[12] covering most of the course's material was used. The use of the textbook was instrumental to provide the students with additional and more in-depth material related to the theory covered in classroom.

Projects

The development of a project, where economic and decision analysis should be used, was a major point of the course. The idea was to allow the participants to freely propose a topic related to their main engineering background, and then use their theoretical knowledge in conjunction

with decision analysis theory to develop a project aiming to address economic issues normally present in the chosen topic.

Clearly, this was not an easy task. "Engineering problem solving is difficulty to teach"[13] and a challenge for educators[14]. Participants were encouraged to decide on a topic by themselves, with the help of their supervisors and the instructor. Various examples of applications of economic and risk analysis in the oil and gas industry were given. Students had the first month of course to choose a topic and define a plan of action on how to develop their projects. It was important, during this initial month, the availability of the instructor to meet with the students in order to clarify doubts and refine the plan of action.

Discussion of the projects developed during the course would be very technical and beyond the scope of this article. However, it is important to mention that most of the projects developed were considered highly creative and above any initial expectations. Most important, the main objective of the course, which was to prepare students to deal with engineering economy issues that are always present in the oil industry, was reached. Students identified, in their research subject, topics that presented technical uncertainties that could have a strong financial impact in the outcome of the project. They used their technical knowledge, and economic and decision analysis tools, to quantify and handle the uncertainties and to investigate the various possible outcomes.

In the two last weeks of the course the projects were presented and evaluated by the instructor and the students in a seminar with presentations, questions and discussions. Examples of projects developed and how risk and economic analysis were used are listed below:

- Production Forecasting and Decision Analysis for an Oil Field;
  - *This project used actual data from an oil field to simulate its productive life over a period of 30 years. In the project decision tree analysis was used to simulate various possible scenarios including changes in oil price, Opex and production methods. Cash flows for the various scenarios were presented.*
- Uncertainty Assessment by Using Experimental Design and Risk Analysis Techniques, Applied to Offshore Heavy Oil Recovery;
- A Probabilistic Approach in Reserves Estimation;
  - *Uncertainty in reserves estimation is inherent to most oil and gas prospects. This project showed the existing probabilistic approaches in reserve determination and the difficulties for implementation of such methods. Main points discussed were uncertainty in capital investment, operating costs and well productivity.*
- Economic Analysis of Athabasca Steam Assisted Gravity Drainage Project;
  - *A project closely related to Canadian oil industry that discussed the main risks involved in that production technology. It included a model of the project as well as key technical drivers that directly reflect on project's profitability. A sensitivity analysis was performed to determine the influence of oil and gas prices and operating costs.*
- Economic Feasibility of the CO_2 Miscible Flooding Process;
  - *This project focused on the application of an EOR (Enhanced Oil Recovery) method. It analyzed which economic factors should be considered when investigating the possibility of using this method. Various scenarios were*

simulated and the results used as input parameters for an economic feasibility study that indicated whether an EOR project should be implemented or not.

- Use of Probabilistic Methods and Risk Analysis to Reduce Oil Well Control Problems.
  - *This report reviewed methods that use quantitative risk analysis techniques to determine reservoir's pore and fracture pressures and how those methods can be used to conduct safer and less costly oil well drilling operations.*

To better exemplify, how economic and risk analysis tools were used, let us briefly describe what was done in the second project of the above list. This project dealt with the complexities existing in the development of heavy oil fields, which is directly associated with the uncertainties in the fluid and reservoir characterization. A probabilistic analysis was used to face these expected uncertainties.

The approach proposed used experimental design techniques to determine the parameters that have large contribution to the Net Present Value (NPV) of the oil field being analyzed. In the example presented, NPV was estimated based on the accumulated oil production simulated over a period of 30 years. An uncertainty analysis was done using the probabilities associated with each of the uncertain parameters. Decision tree technique was used to map all possible outcomes and then to estimate the Expected Monetary Value (EMV).

A program was written to manage the input/output files of a commercial reservoir simulator. The program was used to run a total of 1,728 simulations and estimate the NPV for each one of those parameter combinations. On a second analysis, the uncertainty density distribution was derived based on the histogram of the NPV results and the most probable economic outcome for that particular oil field was determined.

With a few exceptions, most of the projects presented the same level of complexity and creativity of the abovementioned work and incorporated technical disciplines with engineering economy and decision analysis. Less interesting projects presented were the ones where a mere literature review of a certain topic was offered with some indication of the possible use of risk analysis tools for that particular subject.

The Newsletter

Besides connecting the students with real issues of the oil and gas industry, the "Newsletter" had the objective of being a fun instructional tool that would raise the interest on non-technical issues related to their profession, including politics and economics. Sources for the Newsletter were newspapers, magazines, other actual online newsletters, and different internet sources.

Groups of two students, with the exception of one student that worked alone, edited the newsletter on a weekly basis producing twelve issues during the term (two per group). Facsimiles of the front page of two newsletters are presented in Appendix A.

The newsletters were distributed among the students and selected professionals from Academia and Industry. Their feedback on the main important points of each issue was constantly forwarded to the students. Many important issues related to the oil industry were featured on the

newsletters including political issues, environmental regulations, oil and gas prices, new ventures and financing and specific regional issues related to Canada, North America, Africa and Middle East.

A specific assessment of the Newsletter's influence on students' interest for economic issues related to the oil industry was not performed.

Course Evaluation

Course evaluation is mandatory in most of North American universities. The results of the course evaluation presented here should be analyzed considering that the course was taught for the first time to a reduced (11) number of students. The evaluation was made anonymously and without the presence of the instructor.

In the evaluation the students responded to a multiple choice questionnaire and also were encouraged to write answers to 3 questions. The questionnaire had 15 statements and the students used a scale from 1 to 5 to demonstrate agreement or disagreement with each statement. In the way the statements were presented, statements receiving high marks indicated appreciation for the course and/or instructor, while low marks indicated problems with the course. Ten statements had the maximum possible average mark (5), four statements averaged 4.9 and one statement averaged 4.8. As mentioned before, these good results do not allow any conclusion since it came from just one course and a small number of students.

The three non multiple choice questions were partially responded by eight students. Some ignored the questions and just wrote general comments. All significant answers or comments are listed below. "Nice" but meaningless comments about the course and/or the instructor were omitted.

- Which aspects of the course did you like the best?
  - *Organized and informative.*
  - *Risk analysis methods.*
  - *Real case examples, Newsletter.*
  - *Project presentation.*
  - *Content of the course, overview on oil industry economics.*
  - *Decision tree analysis, cash flow.*
- Which aspects of the course did you like least?
  - *Final exam.*
  - *Newsletter (not necessary.)*
- Comment on general course quality.
  - *Connected to industry.*
  - *Could be improved on Monte Carlo simulation.*

Conclusions

A graduate course was developed with the main objective of allowing engineering graduate students, mainly the ones working in natural resource areas such as mining and petroleum, to

incorporate in their education economic and decision analysis tools that are considered extremely important for modern professionals.

The course carries a review on the basics of engineering economy and an advanced treatment of decision analysis topics. An individual project developed by the student is the highlight of the course and allows a truly interface between the conventional technical knowledge and economic and risk analysis.

The initial experience with the course indicated that economic and decision analysis tools can effectively be used to create opportunities for students to solve actual engineering problems while developing deeper learning and preparedness for a career in the industry.

The results presented in the individual projects indicated that students had acquired the skills intended in the new course. However, in order to better support this conclusion, the effectiveness of the course needs to be assessed in future classes so as to have a more robust database. The course is being taught again (Winter, 2006) but not on time to have its results published in this paper.

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APPENDIX A - Nesletter
Frontpage - Example

GRADUATE STUDENTS
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OIL GLOBE NEWS

VOLUME 1, ISSUE 1 THURSDAY, JANUARY 20, 2005

ECONOMICS: WHY ARE OIL PRICES SO HIGH?

BBC News Online. http://news.bbc.co.uk/1/hi/business/3708951.stm

RISING DEMAND

Global economic expansion is driving what the International Energy Agency says is the biggest increase in oil demand for 24 years. There is higher than expected demand in industrialised countries and China's rapidly expanding economy has created a huge demand boost. US demand has risen because of strengthening economic recovery and greater need for higher grade crude oil suitable for processing into petrol (gasoline) for the fuel-hungry Sport Utility Vehicles (SUVs) popular with US drivers. Chinese demand is up 20% over the past year. Traders are betting this rapid growth will continue for several years although there is some chance that the economy will "overheat" and oil demand growth will slacken. Among suppliers only Saudi Arabia has significant spare capacity that it can make available to the market.

LOW STOCKS

Oil companies have tried to become more efficient in recent years and operate with lower stocks of crude oil. This means there is less of a cushion in the market against supply interruptions. Events such as violence in the Middle East, ethnic tension in Nigeria and strikes in Venezuela have had a greater effect on prices in the past year than might have been the case if stock levels were higher.

OPEC STRATEGY

The producers' cartel Opec accounts for about half of the world's crude oil exports and attempts to keep prices roughly where it wants them by trimming or lifting supplies to the market. In the past, Opec ministers tended to wait for prices to dip before agreeing to cut output. China's booming economy is sucking in a huge amount of oil.

But Opec is now acting more aggressively, announcing production cuts to pre-empt any weakening in prices. International oil companies traditionally used times of seasonally weaker demand, when prices were lower, to rebuild stocks. These windows now appear to have been closed. Data error is an additional factor, some analysts say. Consumption forecasts by market experts turned out to be too low. The result was that producers kept supplies even tighter than was needed to prevent rebuilding of stocks.

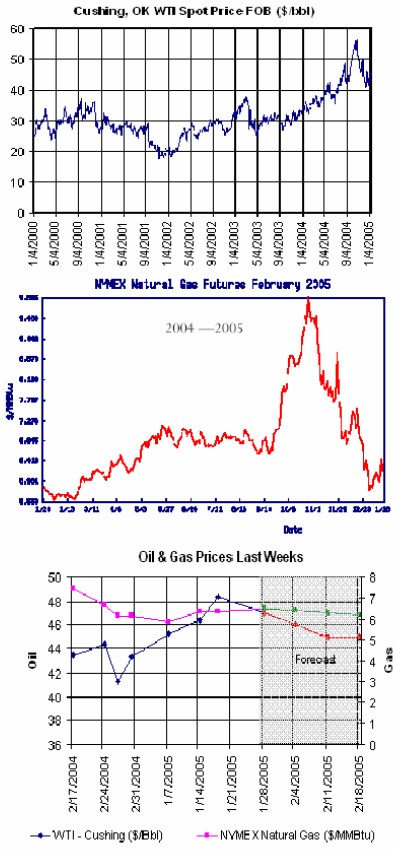
ACTION OF SPECULATORS

The combination of low stocks and Opec action to keep them low leaves the market exposed to the prospect of sudden price rises if supplies are threatened. This has not gone unnoticed by professional market speculators.

Hedge funds and other speculators betting on the possibility of higher prices have themselves exacerbated price pressure in the market. Opec officials tend to blame speculators for 2004's run-up in prices, ignoring the organisation's earlier role in preventing stock rebuilding. Opec argues that its members are now pumping flat-out - which is largely true - and that it is powerless in a situation where factors other than mere supply and demand are at work.

(Continued on page 3).

CRUDE OIL HISTORY PRICE



INSIDE THIS ISSUE:

Iran Minister Says OPEC Won't Let Price Fall Below $34-$35/Bbl.

By Hashem Kalantari. Mon, Jan 17, 2005 21:41 GMT. http://www.slb.com/news/story.cfm?storyid=624940.

TEHRAN - Members of the Organization of Petroleum Exporting Countries won't allow the group's basket price to drop below $34 a barrel, Iran's Oil Minister Bijan Namdar Zangeneh said in an interview with a local newspaper. 'No one in OPEC is willing to see the price of oil below a $34 to $35 ceiling for the organization's oil basket,' he told the daily Sharq newspaper over the weekend.

OPEC's basket price was $41.80/bbl Friday, the group said Monday. Oil prices are now at the highest level in six weeks on cold weather and jitters ahead of OPEC's Jan. 30 meeting following output cuts at the December meeting to defend prices. Zangeneh had earlier said the market was oversupplied by around 1.5 million barrels a day in the first quarter and by about 3 million b/d in the second quarter of the year when demand for crude typically drops.

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OIL GLOBE NEWS

VOLUME I, ISSUE VIII FRIDAY, MARCH 18, 2005.

CRUDE PRICES RISE DESPITE TALK OF OPEC OUTPUT HIKE

Houston, March 15, 2005 http://ogj.pennnet.com/articles/article_display.cfm?article_id=223282

Crude prices climbed as traders shrugged off a Mar. 14 suggestion by Saudi Arabia that the Organization of Petroleum Exporting Countries raise its production quota by 500,000 b/d to 27.5 million b/d at the Mar. 16 meeting of ministers in Isfahan, Iran.

That proposal by Saudi Arabia's Minister of Petroleum and Mineral Resources Ali I. al-Naimi to increase the quota in an effort to deflate crude prices apparently was not well received by other OPEC ministers either. Fathi bin Shatwan, Libya's oil minister, rejected it, saying that OPEC no longer controls the oil market.

Most OPEC members are already producing at capacity. Only Saudi Arabia and Kuwait have measurable volumes in reserve, analysts said. In a Mar. 15 report by Dow Jones Newswires, Ahmad Fahad Al-Ahmd Al-Sabah, Kuwait's energy minister and OPEC's conference president, said ministers with whom he had spoken wanted to defer a production hike until market conditions warrant such a move.

He said the 10 OPEC members currently governed by production quotas, excluding Iraq, are now producing 27.7 million b/d. Therefore, increasing the quota would not add any production.

Energy prices

On the New York Stock Exchange, the April contract for benchmark US sweet, light crudes fell to $53.52/bbl following the Saudi proposal but then rebounded to close at $54.95/bbl, up 52¢ for the day, after trading as high as $55.05/bbl. The May contract increased by 53¢ to $55.65/bbl. On the US spot market, West Texas Intermediate at Cushing, Okla., continued to track the NYMEX near-month contract, moving up by 52¢ to $54.95/bbl.

The April natural gas contract jumped by 36.6¢ to $7.14/MMbtu on NYMEX, "surging to a 12-week high on cool weather forecasts for this week and steady technical buying by the [investment] funds, triggering a bunch of buy-stops after an early break of resistance," said analysts at Enerfax Daily. However, they said, "When the reality of the [sufficient US natural gas] storage situation finally sets in, look for an even quicker drop to the downside."

Meanwhile, heating oil for April delivery dropped by 0.67¢ to $1.536/gal on NYMEX. Gasoline for the same month fell by 1.1¢ to $1.51/gal.

In London, the April contract for North Sea Brent crude escalated by 56¢ to $53.66/bbl on the International Petroleum Exchange.

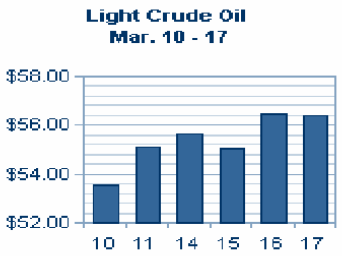
The average price for OPEC's basket of seven benchmark crudes increased by 39¢ to $49.59/bbl on Mar. 14.

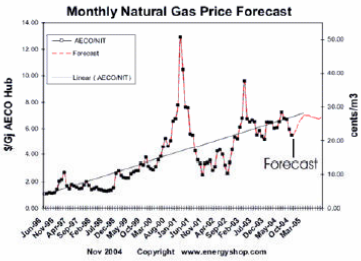
How Will the 'Peak Oil' Scenario Affect Our Global Economy?

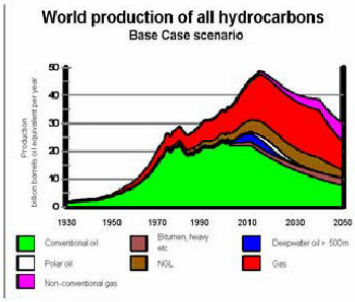
March 14, 2005 (http://www.rigzone.com/news/article.asp?a_id=21066)

Analyses of the discovery and production of global oil fields suggest that world oil production is about to peak, and within the next decade, the supply of conventional oil will be unable to keep up with demand. (Continued on Page 6)

HYDROCARBON CHARTS







INSIDE THIS ISSUE:

OIL CRISIS AHEAD?

March 11, 2005 (An article by Sam Fletcher, http://www.rigzone.com/news/article.asp?a_id=21008)

OPEC is out of spare production, while China is projected to increase its oil demand by 25% in 2005. If this scenario is correct, the current pause in the oil rally may be temporary.

The International Energy Agency stalled crude oil's fall in Europe overnight, as it predicted that China's oil demand will increase by 25% in 2005 to 500,000 barrels per day. The IEA based its forecast on two facts: 1) continued U.S. economic growth, and 2) continued export strength from China. According to Bloomberg's take on the IEA report: "Oil consumption will be 84.3 million barrels a day this year, 330,000 a day more than last expected. Use will rise 1.81 million barrels a day, or 2.2 percent, the Paris-based agency said in a monthly report today."

Here is where it gets interesting. According to Reuters: ["OPEC does not have the production capacity to increase its quotas,"] Algeria's Energy Minister Chakib Khelil said on Thursday. OPEC raised supply last year to the highest level in 25 years, leaving little spare production capacity to cope with output disruptions.".

Today's analysis is linked by two threads, expectations, and contradictions. (Continued on Page 6)